

REFRACTORY CHONDRULE FRAGMENTS WITH CARBONACEOUS CHONDRITE AFFINITIES IN COMET 81P/WILD2. J. C. Bridges¹ and H. G. Changela¹, ¹Space Research Centre, Dept. of Physics & Astronomy, University of Leicester, Leicester UK, LE1 7RH j.bridges@le.ac.uk, hgc3@le.ac.uk

Introduction: The *Stardust* mission results have shown that Comet 81P/Wild2 contains CAI-like material and chondrule fragments derived from the inner Solar System [1-3]. However, the affinities between Wild2 and different chondrite groups and IDPs are not yet clear. Understanding how this Jupiter family comet compares to other planetary materials will enhance our understanding of early Solar System processes such as the transfer of material within the Solar System, the relationships between known chondrite groups, interplanetary dust, asteroids and comets. TEM analyses of terminal grains from the aerogel collectors offer some of the best opportunities to analyse pristine material from the comet and make such comparisons. We report the results of a TEM study which provides evidence for refractory material within Comet Wild2 distinct from the CAI identified by other workers [1-3].

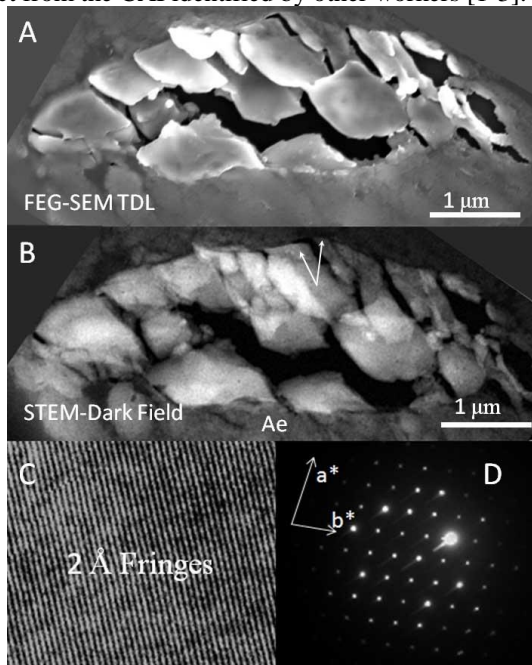


Fig.1. Terminal particle #2 from Track #154, C2063,1,154,1,15. A. SEM image showing Al-diopside surrounded by aerogel. B. STEM dark field image of same grain, with small areas of enstatite arrowed, remainder is Al-diopside. Aerogel (Ae) C. HRTEM image of Al-diopside (from another part of this particle on C2063,1,154,1,15) showing lattice fringes. D. SAED diffraction pattern of Al-diopside from terminal particle #2 on [0 -1 0] zone axis.

Methods and Samples: Terminal particle #2 from C2063,1,154,0,0 (Track #154) was prepared for

TEM analysis by microtome cutting at NASA-JSC. This track is 922 μm length and bulbous (Type B) with 6 terminal particles. We report the results of analyses on 2 TEM grids at the UoL (C2063,1,154,1,14; C2063,1,154,1,15). A Jeol 1200 TEM with a PGT EDS system and LaB₆ source was used for TEM analyses. It was operated at 200 kV and 109-111 μA emission current. Quantitative EDS analyses have been achieved using a Cliff-Lorimer technique and checked with a range of mineral standards e.g. forsteritic olivine similar to that found in Wild2. Bright field imaging, High Resolution TEM (HRTEM), TEM-EDX, STEM bright, dark field and Selected Area Electron Diffraction (SAED) have been performed on the samples. In addition some sections have been imaged by FEG-SEM. These samples are planned to be analysed by other techniques within the UK Stardust consortium.

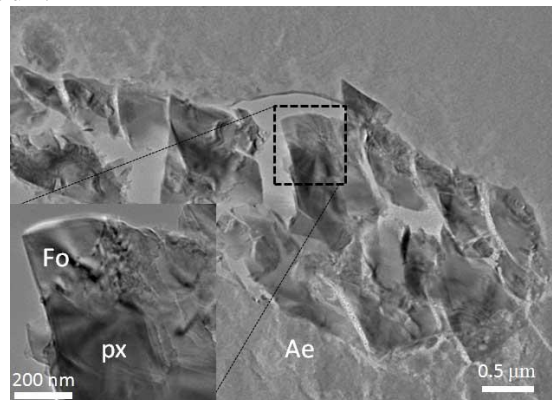


Fig.2. Bright field TEM of C2063,1,154,1,14. This grain is Al-diopside with minor forsterite. Ae aerogel, px Al-diopside. Inset shows the forsterite olivine grain (Fo).

Results: The grain slices on the TEM grids range up to 6.5 by 2.4 μm (Fig. 1) and in total $\sim 20 \mu\text{m}^2$ of this terminal particle has been analysed so far. Most of the terminal particle is composed of Al-rich diopside (Fig. 1, 2). This pyroxene has a lattice spacing of 2Å (Fig.1C). Al₂O₃ contents range from 7.3-15.5 wt% with a range in 100Mg# of 90-100. TiO₂ contents are relatively low (0-1.8 wt%) compared to those of Al-rich diopside (fassaite) within CAIs but similar to that from Al-diopside chondrules (Fig. 3). Small amounts of pure forsterite and enstatite (En 96-99%, Al₂O₃ ≤ 1.9 wt%) are also present but the bulk composition is dominated by the Al-diopside. Minor amounts of Fe-Ni sulphide have been identified at the margins of the ter-

minal grains with surrounding aerogel. No mesostasis-like glass or feldspar or spinel have been identified within the sections examined.

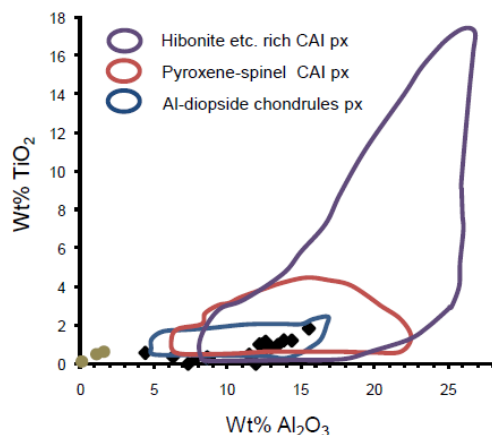


Fig. 3. TiO_2 v. Al_2O_3 composition of Al-diopside (black diamonds $N = 19$, enstatite $N = 3$ brown circles) in terminal particle #2 of Track #154. The Al-diopside has a similar composition to that from Al-diopside rich chondrules identified in HH237 and QUE94411/94627 – meteorites which have affinities to CH and CR chondrites [4]. The particle's pyroxene has a lower range of TiO_2 contents than that associated with high Ca pyroxene from CAIs. Data fields from [4].

Discussion: The range in Al-diopside compositions we have determined is close and parallel to the trend of bulk compositions of Al-rich chondrules (Fig. 4) and distinct from the bulk compositions of CAIs. This is consistent with the Al-diopside being the major constituent of an Al-rich chondrule but if so suggests that other phases not yet seen in TEM sections e.g. mesostasis may also have been present.

The refractory fragment analysed here is clearly distinct from the *Inti* CAI identified in Track #25 which had pyroxene with TiO_2 of 3.7 – 14.5 wt% [3] and also contained other minerals normally associated with CAIs. The presence of enstatite and forsterite in Track #154 are also more consistent with an origin as a fragment of a refractory chondrule than as part of a CAI. Within CAIs diopside-forsterite assemblages are rare and largely confined to some Wark-Lovering rims [5]. Similar Al-rich diopside has also been identified in a hydrated IDP with a TiO_2 content of 0.6 wt% and Al_2O_3 14.5 wt% [6]. This terminal particle is clearly distinct from the majority of complete Al-rich chondrules identified in different chondrite groups which are often plagioclase-rich for instance. There is however a similarity in the pyroxene composition to Al-diopside rich chondrules in the HH237 and QUE94411/94627 chondrites which have CH, CR af-

finities [4]. Osbornite (TiN) within the *Inti* CAI of Track #25 was also noted as present in CH chondrites but having different size and V distributions [3]. Metal enrichment similar to that seen in CH chondrites has not been identified in Wild2.

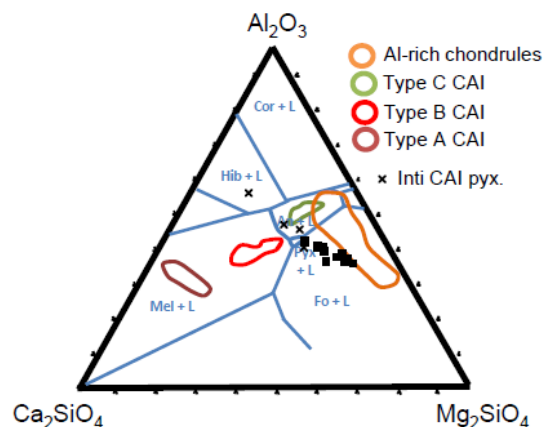


Fig. 4. Al-diopside TEM-EDS analyses ($N = 19$) from terminal particle 2 of Track #154. Bulk compositions of Al-rich chondrules and different CAI types from [5], Ti-rich pyroxene from the *Inti* CAI [3]. The Track #154 Al-rich diopside analyses show a similar trend and overlap with the bulk Al-rich chondrules' analyses, but are distinct from the CAI bulk compositions and most pyroxene from the *Inti* CAI. Plot is a CMAS-type projection from spinel [7].

Conclusions: Track #154 contains a terminal particle (#2) that consists mainly of Al-diopside with small amounts of forsterite, enstatite and Fe-sulphide. The assemblage and pyroxene composition analysed so far are distinct from CAI-like material previously identified in Comet Wild2. They are more consistent with an origin as an incomplete fragment of an Al-rich chondrule with carbonaceous chondrite affinities (e.g. similar to those described in CH, CR groups) derived from the inner Solar System.

References: [1] Zolensky M. E. et al. (2006) *Science*, 314, 1735-1739. [2] Nakamura T. et al. (2008) *Science*, 321, 1664-1667 [3] Ishii H. A. et al. (2008) *Science*, 319, 447-450; Chi M. et al. (2009) *Geochim. Cosmochim. Acta* 73, 7150-7161. [4] Krot A. N. et al. (2001) *Meteoritics & Planet. Sci.*, 36, 1189-1216. [5] MacPherson G. J. 2005 in *Meteorites, Comets & Planets* (ed. A. M. Davis), Elsevier. [6] Tomeoka K. and Buseck P. R. 1985 *Nature*, 314, 338-340. [7] Cox K. G. et al. (1979) *The Interpretation of Igneous Rocks*, Allen & Unwin, 450pp.

Acknowledgements We thank K. Messenger at NASA-JSC for the Track #154 sample and TEM section preparation.